

DISPENSING SYSTEM AND METHOD OF CONTROLLING THE SAME

FIELD OF THE INVENTION

[0001] The present invention relates generally to a dispensing system
5 and a method of controlling the dispensing system. More specifically, the present
invention relates to controlling the dispensing system to dispense a viscous material onto
a workpiece at an actual dispensing rate that is within a minimum deviation of a target
dispensing rate by compensating for changes in operational characteristics of the viscous
material and the dispensing system.

10

BACKGROUND OF THE INVENTION

[0002] Dispensing systems are well known in industrial applications for
dispensing viscous materials such as sealants, adhesives, coatings, and the like onto a
workpiece. These applications may be to seal the workpiece, to adhere the workpiece to
15 another structure, or to coat the workpiece. Changes in the viscosity of the viscous
material being dispensed, wear of components of the dispensing system, and operating
abnormalities such as air bubbles within the dispensing system are common in such
dispensing systems. The changes in operational characteristics of the viscous material
and the dispensing system continuously impact an actual dispensing rate of the viscous
20 material. As a result, the prior art has attempted to provide methods to compensate the
actual dispensing rate to account for such changes.

[0003] One such method is shown in United States Patent No. 5,054,650
to Price, issued October 8, 1991. Price discloses a method of controlling a dispensing
system to dispense a viscous material onto a workpiece. Specifically Price discloses a
25 method of compensating an actual dispensing rate of the viscous material to maintain the
actual dispensing rate within a minimum deviation of a target dispensing rate. However,
Price discloses a method for compensating the actual dispensing rate only once per job
cycle. This periodic compensation frequency does not account for the dynamic
characteristics of the viscous materials during each job cycle and the operating
30 abnormalities that may be encountered during each job cycle.

[0004] Another prior art method is shown in United States Patent No.
5,475,614 to Tofte et al., issued December 12, 1995. Tofte et al. discloses a method of

controlling a dispensing system to dispense chemicals onto a field. Specifically, Tofte et al. discloses a method of compensating an actual dispensing rate of the chemicals to account for wear of components of the dispensing system thereby maintaining the actual dispensing rate within a minimum deviation of a target dispensing rate.

5 **[0005]** The method includes dispensing the chemicals onto the field during a first time period and measuring a pressure of the chemicals after each of a plurality of time increments within the first time period as the chemicals are dispensed. The method continues by determining the theoretical volume of the chemicals dispensed during the first time period based on the pressure measurements during the first time
10 period and an initial compensation factor. An actual volume of the chemicals dispensed during the first time period is simultaneously measured. The theoretical volume dispensed during the first time period is then compared to the actual volume dispensed during the first time period and a first new value for the compensation factor is derived therefrom.

15 **[0006]** The method of Tofte et al. continues by dispensing the chemicals onto the field during a second time period and measuring a pressure of the chemicals after each of a plurality of time increments within the second time period. The method continues, as before, by determining a theoretical volume of the chemicals dispensed during the second time period based on the pressure measurements during the second
20 time period and the first new value for the compensation factor. An actual volume of the chemicals dispensed during the second time period is simultaneously measured. The controller then compares the theoretical and actual volumes of the chemicals dispensed during the second time period and derives a second new value for the compensation factor therefrom. Tofte et al. discloses that the second time period is periodically spaced
25 from the first time period. Tofte et al. is primarily concerned with nozzle wear that occurs during dispensing of the chemicals. Hence, the periodically spaced time periods disclosed by Tofte et al. are sufficient to compensate for such wear since such wear is not immediate, i.e., occurs over several time periods. Conversely, periodically spaced time periods are not sufficient to compensate for changes in viscosity of a viscous
30 material during dispensing. In this case, new values for the compensation factor must be continuously determined.

[0007] In summary Tofte et al. discloses using the compensation factor

to compensate the actual dispensing rate to maintain the actual dispensing rate within the minimum deviation from the target dispensing rate. The compensation factor is recalculated in each time period, e.g., the first and second new values for the compensation factor are determined, by comparing the actual and theoretical volumes of the chemicals dispensed during each of the time periods. The time periods are periodically spaced from one another.

BRIEF SUMMARY OF THE INVENTION

[0008] The present invention provides a method of controlling a dispensing system. The method includes dispensing the viscous material onto the workpiece during a first time period and measuring a pressure of the viscous material after each of a plurality of time increments within the first time period. The method continues by determining the theoretical volume of the viscous material dispensed during the first time period based on the pressure measurements during the first time period and an initial compensation factor. The actual volume of the viscous material dispensed during the first time period is measured and compared to the theoretical volume of the viscous material. A first new value for the compensation factor is determined based on the comparison between the theoretical and actual volumes of the viscous material dispensed during the first time period.

[0009] The method then continues in the same manner for a second time period. More specifically, the viscous material is dispensed onto the workpiece during the second time period and a pressure of the viscous material is measured after each of a plurality of time increments within the second time period. A theoretical volume of the viscous material dispensed during the second time period is determined based on the pressure measurements during the second time period and the first new compensation factor. An actual volume of the viscous material dispensed during the second time period is measured and compared to the theoretical volume of the viscous material dispensed during the second time period. A second new value for the compensation factor is determined based on the comparison between the theoretical and actual volumes of the viscous material dispensed during the second time period.

[0010] The method is characterized by at least a portion of the second time period occurring consecutively with the first time period to compensate for changes

in operational characteristics of the viscous material and the dispensing system thereby maintaining the actual dispensing rate within the minimum deviation of the target dispensing rate.

5 **[0011]** The present invention provides several advantages over the prior art, including Tofte et al. For instance, by determining the second new value for the compensation factor consecutively with determining the first new value for the compensation factor, the dispensing system can more quickly compensate the actual dispensing rate in the second time period for the changes in operational characteristics of the viscous material and the dispensing system during the first time period. Such
10 changes include changes in viscosity, air bubbles in the dispensing system, plugged nozzles, and the like. As previously discussed, these changes can have an immediate impact on the actual dispensing rate of the viscous material. For instance, a change in viscosity requires immediate compensation to ensure that the viscous material is being dispensed within the minimum deviation of the target dispensing rate. The dispensing
15 system and method of controlling the dispensing system of the present invention accomplishes this by continually determining a new value for the compensation factor, i.e., recalculating the compensation factor. As a result, the method of the present invention provides a better quality seal in the case of the viscous material being a sealant, and saves costs by reducing excessive dispensing.

20

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0012] Advantages of the present invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

25 **[0013]** Figure 1 is a schematic view of a dispensing system of the present invention;

[0014] Figure 2 is a perspective view of a robot used in the dispensing system of the present invention;

30 **[0015]** Figure 3 is a graph illustrating changes in voltage applied to a variable orifice servo valve of the present invention during first and second time periods;

[0016] Figure 4 is a graph illustrating changes in theoretical and actual volumes of viscous material dispensed during the first and second time periods;

[0017] Figure 5 is a graph illustrating changes in theoretical and actual volumes of the viscous material relative to a target volume during the first and second time periods; and

[0018] Figure 6 is a graph illustrating changes in theoretical and actual volumes of the viscous material dispensed during first and second time periods in an alternative embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0019] Referring to the Figures, wherein like numerals indicate like or corresponding parts throughout the several views, a dispensing system for dispensing a viscous material **10** onto a workpiece **12** at an actual dispensing rate that is within a minimum deviation of a target dispensing rate is generally shown at **14**.

DISPENSING SYSTEM

[0020] The dispensing system **14** of the present invention is preferably used in industrial applications that require accurate dispensing of the viscous material **10** onto the workpiece **12**. Such applications may include, but are not limited to, dispensing paint onto the workpiece **12**, dispensing sealant onto the workpiece **12** to seal the workpiece **12** from moisture, or dispensing an adhesive onto the workpiece **12** to affix the workpiece **12** to a separate structure.

[0021] Referring to FIG. 1, a container **16** stores the viscous material **10** to be dispensed. A pump **18** receives the viscous material **10** from the container **16** and conveys the viscous material **10** through a delivery conduit **20** having upstream **22** and downstream **24** ends. The delivery conduit **20**, in turn, carries the viscous material **10** toward the workpiece **12**.

[0022] A nozzle **26** is coupled to the delivery conduit **20** at the downstream end **24**. The nozzle **26** directs the viscous material **10** onto the workpiece **12** while the pump **18**, which is coupled to the delivery conduit **20** at the upstream end **22**, conveys the viscous material **10** through the delivery conduit **20** to the nozzle **26**.

[0023] Referring to FIGS. 1 and 2, a robot **28** is used to control a position of the nozzle **26** relative to the workpiece **12** while the viscous material **10** is dispensed from the nozzle **26**. More specifically, the robot **28** includes a robot arm **30**

that engages the nozzle 26 to move the nozzle 26 to control positioning of the nozzle 26 relative to the workpiece 12. Those skilled in the art understand that the robot arm 30 could also engage the workpiece 12 near the nozzle 26 and move the workpiece 12 relative to the nozzle 26. In this instance, the nozzle 26 would be fixed. The robot 28
5 defines six rotational axes A1-A6 for rotating thereabout. The robot 28 is preferably a dispensing robot that is modularly constructed and electric servo-driven.

[0024] A flow meter 32 is coupled to the delivery conduit 20 to measure an actual volume of the viscous material 10 dispensed onto the workpiece 12. The flow meter 32 is positioned downstream of the pump 18 and upstream of the nozzle 26. The
10 flow meter 32 is preferably a screw-type or gear-type volumetric flow meter 32 that transmits an electrical pulse 34 after a preset volume of the viscous material 10 has passed therethrough. Hence, the actual volume measured by the flow meter 32 is always the preset volume. In a typical dispensing application, the flow meter 32 transmits a pulse 34 every 0.09 to 0.3 seconds thereby indicating that the preset volume of viscous
15 material 10 has passed therethrough. For instance, referring briefly to FIG. 4, a first pulse 34a indicates that the preset volume of the viscous material 10 has passed through the flow meter 32 during a first time period T1 and the second pulse 34b indicates that the preset volume of the viscous material 10 has passed through the flow meter 32 during a second time period T2, consecutive with the first time period T1. In a typical
20 dispensing application, which dispenses a total volume hundreds of times larger than the preset volume, a stream of pulses 34 is transmitted.

[0025] Referring back to FIG. 1, a pressure sensor 36 is positioned at the nozzle 26 to measure a pressure of the viscous material 10 as the viscous material 10 is dispensed onto the workpiece 12. The pressure sensor 36 includes a transducer 38
25 positioned within the nozzle 26 that transmits a control signal 40 that varies as the pressure of the viscous material 10 within the nozzle 26 varies. The pressure sensor 36 measures the pressure after each of a plurality of time increments t_i while the viscous material 10 is being dispensed. In the preferred embodiment, each of the plurality of time increments t_i are 0.008 seconds. Hence, in a typical dispensing application,
30 referring back to the frequency of pulses 34 from the flow meter 32, several pressure measurements P are taken for every pulse 34 transmitted by the flow meter 32. See FIGS. 3-6.

[0026] A pressure regulator 42 is coupled to the delivery conduit 20 to control the actual dispensing rate that the viscous material 10 is dispensed through the nozzle 26 and onto the workpiece 12. The pressure regulator 42 includes a variable orifice servo valve 44 that is electronically responsive to an output signal 46 to open and close the variable orifice servo valve 44 thereby changing the actual dispensing rate. The output signal 46 comprises a voltage to be applied to the variable orifice servo valve 44 to maintain a position of the variable orifice servo valve 44. Additions or reductions to the voltage adjusts the variable orifice servo valve 44 to ensure that the viscous material 10 is being dispensed within the minimum deviation of the target dispensing rate, as will be described further below. Operation of the flow meter 32, pressure sensor 36, and pressure regulator 42 are well known to those skilled in the art and will not be described in further detail.

[0027] A controller 48 having a microprocessor 49 is operatively and electrically connected to the flow meter 32, the pressure sensor 36, and the pressure regulator 42. The controller 48 is programmed to receive and interpret the pulses 34 transmitted by the flow meter 32 to measure the actual volume of the viscous material 10 dispensed over time. The controller 48 is also programmed to receive and interpret the control signal 40 generated by the pressure sensor 36 to determine a theoretical volume of the viscous material 10 dispensed onto the workpiece 12 over time. The controller 48 compares the theoretical volume and the actual volume to derive new values for a compensation factor f , as will be described further below.

[0028] It should be appreciated by those skilled in the art that alternative configurations of the dispensing system 14 could also be envisioned without departing from the spirit of the present invention.

METHOD OF CONTROLLING THE DISPENSING SYSTEM

[0029] In typical dispensing applications, the viscous material 10, e.g., urethanes, silicones, butyls, hot-melt materials, and the like, may have a standard viscosity between 10,000 and 500,000 cP (mPa · s). In addition, the viscosity of the viscous material 10 may vary due to temperature, shear thinning or thickening, and batch-to-batch changes. At the same time, changes in the dispensing system 14 may occur such as wear of components, e.g., wear of the nozzle 26, plugging of the nozzle

26, air bubbles within the dispensing system 14, the viscous material 10 settling during breaks, and the like. The dispensing system 14 of the present invention utilizes the compensation factor **f** and closed loop control to compensate the actual dispensing rate of the viscous material 10 for changes in these operational characteristics of the viscous material 10 and the dispensing system 14 such that the actual dispensing rate is maintained within the minimum deviation of the target dispensing rate. The minimum deviation represents an acceptable tolerance in the actual dispensing rate. Typically such tolerances are on the order of ten percent, i.e., the actual dispensing rate is within ten percent of the target dispensing rate.

10

Operation of the Dispensing system

[0030] Operation of the dispensing system 14 is based on the pressure measurements **P** taken while dispensing the viscous material 10 onto the workpiece 12. In other words, dispensing of the viscous material 10 onto the workpiece 12 is pressure controlled.

15

[0031] Referring to FIG. 3, the pressure of the viscous material 10 is measured after each of the plurality of time increments **ti** as the viscous material 10 is dispensed. As previously noted, the pressure sensor 36 transmits the control signal 40 to the controller 48 after each of the plurality of time increments **ti** and the controller 48, receiving the control signal 40, converts the control signal 40 into the pressure measurements **P**.

20

[0032] A theoretical dispensing rate is determined after each pressure measurement **P** is taken. These theoretical dispensing rates are determined using the equation,

25

$$\text{theoretical dispensing rate} = [(P - b) / f]^N$$

wherein **f** is the compensation factor, **b** is a cracking pressure, **P** is the pressure measurement, and **N** is the linearity factor. The cracking pressure **b** represents the minimum pressure for the viscous material 10 to begin dispensing from the dispensing system 14 onto the workpiece 12, i.e., the cracking pressure **b** compensates for frictional losses within the dispensing system 14. The linearity factor **N** corresponds to shear

30

thinning or shear thickening properties of the viscous material **10**. For instance, the linearity factor **N** may be less than one for shear-thickening, greater than one for shear-thinning, and equal to one for linear material. As will be appreciated by those skilled in the art, the cracking pressure **b** and linearity factor **N** can be established based on trial and error using the above equation or by other methods such as manufacturer's suggestions and the like. Determination, e.g., calculation, of the compensation factor **f** is described further below.

[0033] Referring back to FIG. 1, after each of the plurality of time increments **ti**, the corresponding theoretical dispensing rate is compared to the target dispensing rate. The dispensing system **14** is then adjusted based on the difference between the theoretical dispensing rate and the target dispensing rate. More specifically, the variable orifice servo valve **44** is adjusted. For example, if the theoretical dispensing rate is greater than the target dispensing rate the variable orifice servo valve **44** partially closes flow of the viscous material **10**, and if the theoretical dispensing rate is less than the target dispensing rate the variable orifice servo valve **44** partially opens flow of the viscous material **10**.

[0034] The variable orifice servo valve **44** is adjusted by adjusting the voltage of the output signal **46** applied thereto. In the preferred embodiment, the voltage of the output signal **46** comprises a base voltage **50**, a first voltage adjustment **52**, and a second voltage adjustment **54**. The base voltage is predefined, for example, by a relationship such as,

$$\text{base voltage} = A * \text{target dispensing rate} + \text{initial voltage}$$

wherein **A** is a constant. Referring specifically to FIG. 1, once the difference between the theoretical dispensing rate and the target dispensing rate is determined after each time increment, the difference is multiplied by a first voltage constant **K₀** to determine the first voltage adjustment **52**. The first voltage adjustment **52** can be an addition or reduction of the voltage of the output signal **46** applied to the variable orifice servo valve **44** to ensure that the actual dispensing rate is within the minimum deviation of the target dispensing rate. The second voltage adjustment **54** is described further below in reference to additional compensation routines.

[0035] This method of controlling the dispensing system 14 to dispense the viscous material 10 would not be ideal without the compensation factor f to determine the theoretical dispensing rate. Controlling the dispensing system 14 based on the theoretical dispensing rate, without the compensation factor f , would not account for many of the changes in the operating characteristics of the viscous material 10 and the dispensing system 14. Hence, the dispensing system 14 would be prone to errors, resulting in wasted time and increased product defects. For this reason, the compensation factor f is utilized.

10 Determining the Compensation factor

[0036] The compensation factor f is utilized during operation of the dispensing system 14 to compensate the actual dispensing rate and maintain the actual dispensing rate within the minimum deviation of the target dispensing rate. The compensation factor f , therefore, must be continuously updated, i.e., recalculated, to compensate for changes in the operational characteristics of the viscous material 10 and the dispensing system 14.

[0037] The compensation factor f is determined, i.e., recalculated, after every pulse 34 that is transmitted to the controller 48 by the flow meter 32. Since the flow meter 32 can provide accurate volumetric measurements of the viscous material 10 dispensed over a given time period, these measurements are used to determine the compensation factor f . Of course, as previously noted, these measurements occur approximately once every 0.09 to 0.12 seconds in a typical dispensing application.

[0038] The compensation factor f is determined during operation of the dispensing system 14, i.e., while dispensing the viscous material 10 onto the workpiece 12. As the viscous material 10 is dispensed, the pressure measurements P are being taken after each of the plurality of time increments t_i . Referring to FIG. 4, a theoretical volume of the viscous material 10 dispensed during a first time period T_1 is determined based on the pressure measurements P taken during the first time period T_1 and an initial value f_{initial} for the compensation factor f . The theoretical volume of the viscous material 10 dispensed over the first time period T_1 is determined using the equation,

$$\text{theoretical volume} = \sum_{T_1} [(P_i - b) / f_{\text{initial}}]^N$$

wherein f_{initial} is the initial value for the compensation factor f , b is the cracking pressure, P_{ti} is the pressure measurement taken at each time increment ti within the first time period $T1$, and N is the linearity factor. Since this is the first time period $T1$ in the dispensing application, the compensation factor f has not yet been determined. Hence, the initial value for the compensation factor f_{initial} is arbitrarily selected. As will be seen, however, this arbitrary selection is corrected after the first time period $T1$.

[0039] At the same time, the actual volume of the viscous material 10 dispensed during the first time period $T1$ is measured. In the preferred embodiment, this is simply the preset volume of the flow meter 32, i.e., the volume of the viscous material 10 dispensed between commencement of dispensing at time equals zero in FIG. 4, and the first pulse 34a from the flow meter 32, also shown in FIG. 4. The controller 48 compares the theoretical and actual volumes of the viscous material 10 dispensed during the first time period $T1$ to determine a first new value f_1 for the compensation factor f .

[0040] In particular, the actual volume is equated to the theoretical volume in the equation,

$$\text{actual volume} = \text{theoretical volume} = \sum_{T1} [(P_{ti} - b) / f_1]^N$$

wherein f_1 is the first new value for the compensation factor f , b is the cracking pressure, P_{ti} is the pressure measurement taken at each time increment ti within the first time period $T1$, and N is the linearity factor. The first new value f_1 for the compensation factor f is determined by rearranging this equation as follows,

$$f_1 = \sum_{T1} [(P_{ti} - b)^N / \text{actual volume}]^{(1/N)}$$

[0041] The first new value f_1 for the compensation factor f accounts for changes in operational characteristics of the viscous material 10 and the dispensing system 14 that occurred during the first time period $T1$. Hence, the first new value f_1 for the compensation factor f can now be used for normal operation of the dispensing system 14 in a second time period $T2$, consecutive with the first time period $T1$.

[0042] Still referring to FIG. 4, the method continues by dispensing the

viscous material **10** onto the workpiece **12** during the second time period **T2**. The same steps carried out for the first time period **T1** are performed during the second time period **T2** to determine a second new value f_2 for the compensation factor **f** for the second time period **T2**, namely, measuring a pressure of the viscous material **10** after each of a plurality of time increments t_i within the second time period **T2**, determining a theoretical volume of the viscous material **10** dispensed during the second time period **T2** based on the pressure measurements **P** during the second time period **T2** and the first new compensation factor f_1 , measuring an actual volume of the viscous material **10** dispensed during the second time period **T2**, and comparing the theoretical and actual volumes of the viscous material **10** dispensed during the second time period **T2** to determine the second new value f_2 for the compensation factor **f** based on the comparison between the theoretical and actual volumes of the viscous material **10** dispensed during the second time period **T2**. As will be appreciated, the second new value f_2 for the compensation factor **f** would be utilized while dispensing the viscous material **10** in a third time period (not shown) consecutive with the second time period **T2**.

[0043] The method of determining the first f_1 and second f_2 new values for the compensation factor **f** is characterized by at least a portion of the second time period **T2** occurring consecutively with the first time period **T1** to compensate the actual dispensing rate in the second time period **T2** for changes in the operational characteristics of the viscous material **10** and the dispensing system **14** that occurred in the first time period **T1** thereby maintaining the actual dispensing rate within the minimum deviation of the target dispensing rate. By continuously recalculating new values for the compensation factor **f**, changes in viscosity of the viscous material **10**, wear of the nozzle **26**, occurrences of the nozzle **26** being plugged, air bubbles within the dispensing system **14**, and the like can be continuously monitored and compensated for.

[0044] Of course, this process continues indefinitely for the duration of the dispensing application. In the preferred embodiment, a new value for the compensation factor **f** is determined after each pulse **34** is transmitted by the flow meter **32**, i.e., the compensation factor **f** is recalculated after each pulse **34**. In other words, the previous description of how to determine the first f_1 and second f_2 new values for the compensation factor **f** is merely illustrative of the steps carried out to recalculate the

compensation factor **f** after each pulse **34**. In fact, the compensation factor **f** could be recalculated hundreds or thousands of times during the dispensing application.

Additional Compensation

5 **[0045]** In addition to recalculating and using the compensation factor **f** during normal operation of the dispensing system **14**, other compensation routines can be performed by the controller **48** to ensure that the actual dispensing rate is within the minimum deviation of the target dispensing rate.

[0046] In the preferred embodiment, a theoretical accumulated volume
10 of the viscous material **10** dispensed over the first **T1** and second **T2** time periods is determined. Referring to FIG. 5, the theoretical accumulated volume is based on both the theoretical volume and the actual volume. In particular, the theoretical accumulated volume is based on the theoretical volume between pulses **34a,34b**, and the actual volume at each pulse **34a,34b**. In other words, the theoretical accumulated volume is
15 estimated between pulses **34a,34b** using the equation,

$$\text{theoretical accumulated volume} = \sum t [(P_{ti} - b) / f]^N$$

 wherein **f** is the applicable value for the compensation factor **f**, i.e., **f_{initial}** for the first time
20 period **T1** and **f₁** for the second time period **T2**, **b** is the cracking pressure, **P_{ti}** is the pressure measurement taken at each time increment **ti** within the time periods **T1**, **T2**, and **N** is the linearity factor. The theoretical accumulated volume is adjusted at each pulse **34a,34b** to a total actual volume of viscous material **10** dispensed based on the preset volume of the flow meter **32**, as illustrated in FIG. 5.

25 **[0047]** A target accumulated volume of the viscous material **10** dispensed over the first **T1** and second **T2** time periods is determined based on the target dispensing rate, e.g., the target dispensing rate * time. These accumulated volumes are then compared and the voltage of the output signal **46** applied to the variable orifice servo valve **44** is further adjusted based on the difference between the theoretical
30 accumulated volume and the target accumulated volume. In particular, referring to FIG. 1, the difference is multiplied by a second voltage constant **K₁** to determine the second voltage adjustment **54**. The second voltage adjustment **54** is an addition or reduction in

the voltage of the output signal 46 applied to the variable orifice servo valve 44. Hence, the voltage applied to the variable orifice servo valve 44 via the output signal 46 is equal to the base voltage 50 plus the first 52 and second 54 voltage adjustments. The first voltage adjustment 52, as with the second voltage adjustment 54, is executed after each
5 pressure measurement P, or every 0.008 seconds.

Error Detection

[0048] The compensation factor f can also be used to detect changes in the operational characteristics of the dispensing system 14. In particular, if changes in
10 the value for the compensation factor f between pulses 34 exceeds a predetermined limit, e.g., if the difference between the first new value f_1 for the compensation factor f and the second new value f_2 for the compensation factor f exceeds the predetermined limit, the nozzle 26 may be plugged and the controller 48 may send an indicator signal to an operator of the dispensing system 14 indicating the same. In addition, the controller 48
15 may shut down the dispensing system 14 until the condition is returned to normal, i.e., the nozzle 26 is unplugged.

[0049] The compensation factor f could similarly be used to detect air bubbles within the dispensing system 14 based on the difference between the first f_1 and second f_2 new values for the compensation factor f . For instance, a second
20 predetermined limit may be defined to detect air bubbles with the dispensing system 14. In other words, a plugged nozzle or air bubbles in the dispensing system 14 can be detected by a large change in the compensation factor f within a short time period.

[0050] The compensation factor f could similarly be used to detect undesired “gumdrop” dispensing, i.e., when large drops of the viscous material 10 are
25 dispensed onto the workpiece 12 as opposed to a steady flow.

[0051] In addition, wear of the nozzle 26 of the dispensing system 14 could be detected based on exceeding a predefined limit for the value for the compensation factor f . The predefined limit being a value of the compensation factor f in which the nozzle 26 is close to being worn and must be replaced due to excessive
30 wear. In one embodiment of this feature, the controller 48 may calculate a trend line for each successively determined value of the compensation factor f during the dispensing application. If the trend line does not sharply move, e.g., indicating that the nozzle 26 is

plugged or air bubbles are in the dispensing system 14, and the trend line passes through the predefined limit, i.e., exceeds the predefined limit, an indicator signal may be sent to the operator indicating that the nozzle 26 should be replaced.

5 **Alternative Embodiments**

 [0052] In an alternative embodiment, illustrated in FIG. 6, a portion of the second time period T2 overlaps the first time period T1 such that the second time period T2 includes the first time period T1 to compensate the actual dispensing rate for changes in the operating characteristics of the viscous material 10 and the dispensing system 14 thereby maintaining the actual dispensing rate within the minimum deviation of the target dispensing rate. This alternative may provide a better averaging method for the compensation factor *f* by utilizing more historical pressure and volume data. Other than the difference in the time periods used in the previously outlined steps, all other steps from the previous embodiment are carried out in this embodiment.

15 [0053] Obviously, many modifications and variations of the present invention are possible in light of the above teachings. The invention may be practiced otherwise than as specifically described within the scope of the appended claims. The novelty is meant to be particularly and distinctly recited in the “characterized by” clause whereas the antecedent recitations merely set forth the old and well-known combination
20 in which the invention resides. These antecedent recitations should be interpreted to cover any combination in which the novelty exercises its utility. In addition, the reference numerals in the claims are merely for convenience and are not to be read in any way as limiting.